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Forest Health Protection

Pacific Southwest Region
Northeastern California Shared Service Area

Date: April 10, 2014
File Code: 3420

To: District Ranger, Feather River Ranger District, Plumas National Forest

Subject: Insect and Disease Evaluation of the Sacketts Project (FHP Report NE14-03)

Summary

At the request of Dan Roskopf, District Silviculturist, Feather River Ranger District, Danny Cluck, Forest Health Protection Entomologist, conducted a field evaluation of the Sacketts project on September 11, 2013. The objective of this visit was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss treatment alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density and increasing resiliency to disturbance events such as insect outbreaks, drought and fire. Dan Roskopf, Ryan Tompkins (Forest Silviculturist) and Errol Solomon (District Culturist) participated in the evaluation.

Key findings:

- Current tree mortality is minimal throughout the project area but evidence exists of elevated mortality levels during recent periods of drought.
- Douglas-fir tussock moth-caused defoliation of white fir is occurring in a few areas within the vicinity of Gibsonville. Many of these trees were also recently defoliated by white fir sawfly.
- Heterobasidion root disease was found in portions of the project area contributing to white fir mortality and to the failure of several trees that were subjected to wind throw.
- Overstocking is putting some stands on poorer sites at risk to elevated levels of bark beetle-caused tree mortality during periods of drought.
- An increase in white fir has reduced the number of shade intolerant pines on some south facing slopes and ridge tops.
- Dwarf mistletoe and Cytospora canker infection levels are negatively impacting some red fir stands, reducing tree vigor and predisposing trees to bark and woodboring beetle attacks.
- White pine blister rust is infecting western white pine and negatively impacting regeneration.

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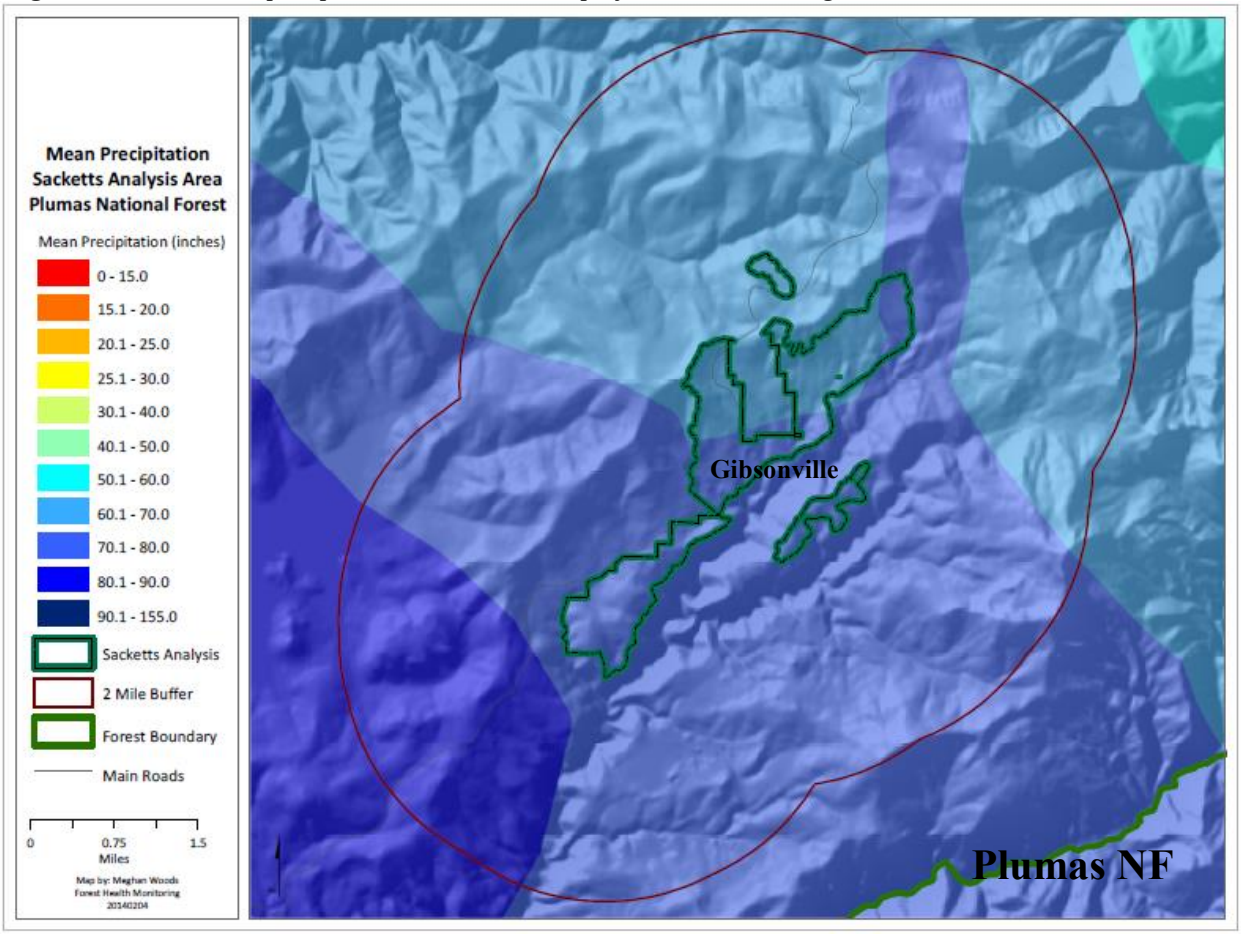
- High fuels loads, consisting of an abundance of dead-down trees and live and dead brush have put some stands at risk to increased fire behavior.
- Thinning is proposed throughout the project area to reduce stocking levels. Specific recommendations are provided in this evaluation.

Description of the project area

The Sacketts project is located approximately 3 miles northeast of La Porte, CA at elevations ranging between 5,200 and 6,400 feet (39° 45' 06.45"N and 120° 54' 55.19"W). Annual precipitation ranges between 60 and 80 inches (Figure 1). Most of the area is comprised of Sierra mixed conifer consisting of white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), ponderosa pine (*Pinus ponderosa*) and incense cedar (*Calocedrus decurrens*). Red fir (*Abies magnifica*) is mixed with white fir and western white pine (*Pinus monticola*) at the highest elevations. California black oak (*Quercus kelloggii*) is mixed with conifers at lower elevations. Many areas are densely stocked, mostly with white fir and contain evidence of recent bark beetle activity in the form of standing and down dead trees.

Figure 1. Mean annual precipitation for the Sacketts project and surrounding area.



Management objectives

The Sacketts project proposes to improve forest health through thinning. Stands will be thinned down to levels that maintain 40 – 50 % canopy cover on average. White fir will be removed in

favor of retaining other tree species. The residual stands will be more open, increasing the amount of available soil moisture and sunlight for individual trees.

Forest insect and disease conditions

Current bark beetle activity is limited primarily to white fir where fir engraver beetle (*Scolytus ventralis*) is causing low levels of scattered tree mortality in association with Heterobasidion root disease (caused by *Heterobasidion occidentale,* formerly referred to as S-type annosus root disease) (Figure 2). Confirmed and suspected Heterobasidion root disease pockets were located within true fir stands throughout the project area (observations made in Units 782, 647, 555, 549 and 541) (Figure 3). Heterobasidion root disease was also associated with wind thrown trees northeast of Gibsonville in Unit 647 (Figure 4).

Figure 2. White fir killed by fir engraver beetle. Trees were likely infected with Heterobasidion root disease.

Figure 3. White fir stump with fruiting body (conk) of *Heterobasidion occidentale*.

Figure 4. Wind thrown white fir with decayed roots.

A review of Forest Health Protection aerial detection survey data from 2009 – 2012 reveals elevated levels of white fir mortality caused by fir engraver beetle throughout the project area, especially in 2010. Scattered mortality of large diameter sugar pine, killed by mountain pine beetle (*Dendroctonus ponderosae*), was also observed during recent aerial surveys.

Douglas-fir tussock moth (O*rgyia pseudotsugata*) and white fir sawfly (*Neodiprion abietis*) have both caused moderate to high levels of white fir defoliation within and adjacent to the project area. White fir sawfly activity began in 2011 and peaked in 2012 causing severe defoliation in some stands. Some of the same trees that sustained heavy defoliation in 2011 and 2012 from white fir sawfly were also defoliated by Douglas-fir tussock moth in 2013. A few of these trees may die from defoliation alone or may be attacked by fir engraver beetle in 2014.

High levels of red fir dwarf mistletoe (*Arceuthobium abietinum* f. sp. *magnificae*) and Cytospora canker (*Cytospora abietis*) were observed in red fir stands in Unit 782 causing branch flagging

and reducing live crown ratio of infected trees. A couple of large diameter red fir in this area were dying from attacks by fir engraver beetle and woodboring beetles (Families: Buprestidae and Cerambycidae).

White pine blister rust (*Cronartium ribicola*) was found causing top kill and branch flagging in mature western white pine in Unit 782. Western white pine regeneration was also heavily infected with white pine blister rust stem cankers.

Stand conditions and mortality related to recent and future climate trends

Many of the forested areas in the Sacketts project appear to be at or above "normal" stocking levels and have sustained low levels of bark beetle-caused mortality, mainly associated with diseases and drought (Figure 5 and Table 1). This mortality combined with high stand density has resulted in heavy fuel loading in many areas and a corresponding increase in potential fire behavior.

Figure 5 also depicts many areas where no mortality was mapped during the past 10 years. This does not necessarily indicate the existence of healthy forest conditions. Many stands within this "mortality free" zone are at an elevated risk to bark beetle and/or root disease-caused tree mortality due to overstocked conditions and could experience unacceptable levels of tree mortality during future droughts.

Figure 5. Areas of elevated tree mortality mapped by Aerial Detection Surveys (ADS) between 2004 and 2013.

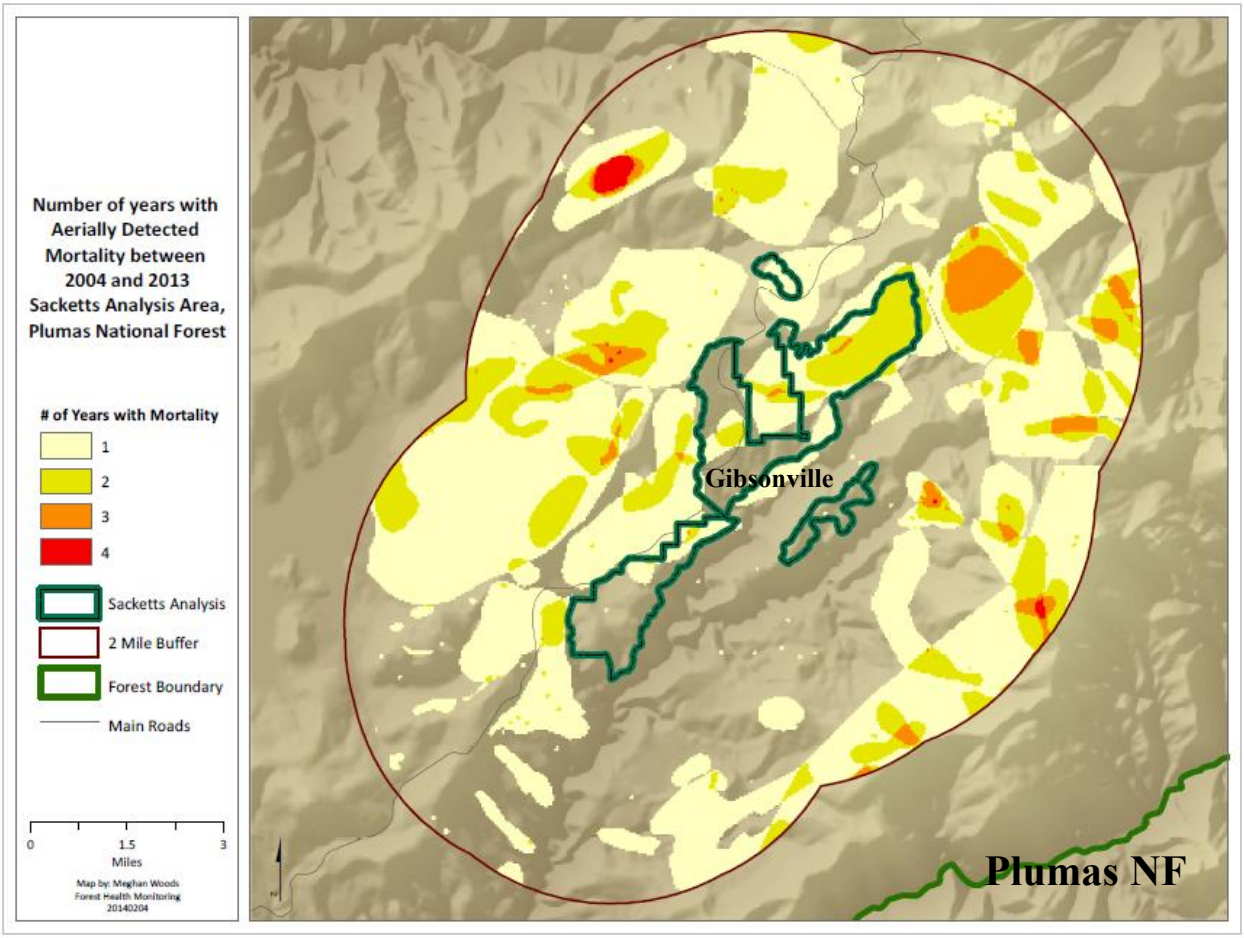


Table 1. Acres with mortality, estimated dead trees per acre and estimated total # of dead trees from R5 Aerial Detection Surveys and Palmer Hydrologic Drought Index (PHDI) (Division 2) by water year (Oct-Sept) within and adjacent to the Sacketts project area.

Year	Acres	Estimated Dead Trees/Acre	Estimated Total # of Dead Trees	PHDI[1]
2013	59	6	377	-1.62
2012	730	1	943	0.37
2011	1,022	1	1,195	2.59
2010	3,243	3	9,502	0.19
2009	473	2	906	-2.69
2008	7	4	32	-2.74
2007	129	1	66	-2.74
2006	2	4	9	2.9
2005	1,367	0	684	0.38
2004	9,925	2	15,864	-1.29

[1] PHDI values ranging from -2.00 to -2.99 are considered moderate drought conditions. Severe drought conditions range from -3.00 to -3.99 and extreme drought conditions are below -4.00.

Successive dry years can exacerbate unhealthy stand conditions, such as those that exist in several portions of the Sacketts project area. This typically results in higher levels of bark beetle-caused tree mortality. From 2008 to 2010, tree mortality generally increased throughout northeastern California as a result of drier than normal conditions. In the Sacketts project area, tree mortality increased dramatically in 2010 (Table 1) in response to drought. A return to normal to above normal precipitation in 2010 and 2011 reduced moisture stress and subsequently reduced mortality levels by 2013. This same pattern of mortality following drought also occurred from 2002 to 2004. The current drought will most likely result in a return to increased tree mortality over the next couple of years.

Predicted climate change is likely to impact trees growing in the Sacketts over the next 100 years. Although no Plumas National Forest specific climate change models are available at this time, there is a general consensus among California models that summers will be drier than they are currently. This prediction is based on the forecasted rise in mean minimum and maximum temperatures and remains consistent regardless of future levels of annual precipitation (K. Merriam and H. Safford, *A summary of current trends and probable future trends in climate and climate-driven processes in the Sierra Cascade Province, including the Plumas, Modoc, and Lassen National Forests*. The risk of bark beetle caused tree mortality will likely increase for all conifer species under this scenario, especially drought intolerant white fir. Improving the resilience of stands to future disturbance events through density, size class and species composition management will be critical to maintaining a healthy forested landscape.

Considerations for thinning treatments

Tree mortality directly attributable to insects and/or pathogens is occurring at low levels within the Sacketts project area. This condition is typical for this forest type on the west side of the Sierra Nevada range due to the very high annual precipitation and high site quality. However, many stands are overstocked and have sustained elevated levels of bark beetle-caused mortality during recent droughts.

The Sacketts project area has become very dense with white fir through past management activities and with the exclusion of fire over the past 100+ years. With such a high percentage of white fir in the area, shade intolerant species such as ponderosa pine and black oak, as well as many shrub species, tend to decline due to competition for sunlight, water and nutrients. Higher percentages of white fir in mixed conifer stands can also increase susceptibility to defoliation events caused by the Douglas-fir tussock moth (a current pest condition). In California, white fir is the preferred host species for the Douglas-fir tussock moth and outbreaks have tended to occur on ridge tops, upper slopes and generally poorer sites with high percentages of white fir. Past outbreaks where heavy defoliation has occurred resulted in approximately 20 - 25 % mortality with lower levels of top kill. Management practices that increase stand vigor, increase species diversity and promote even aged stand characteristics for the white fir component will increase resistance to Douglas-fir tussock moth.

Some stands on south facing slopes and ridge tops within the Sacketts project area contain scattered large diameter ponderosa and sugar pine (Figure 6). Large pines were observed in Units 647, 555, 549 and 541. Thinning treatments that improve growing conditions for these more shade intolerant species, such as removing a large percentage of the white fir basal area around these trees, would increase their health and vigor, create opportunities for their successful regeneration and improve overall resiliency to disturbance agents (insects, disease, drought and fire). Removing competing trees from the base of large diameter pines combined with stand level thinning has resulted in a measured increase in annual increment growth in old growth ponderosa and Jeffrey pine on the Lassen National Forest (FHP unpublished data).

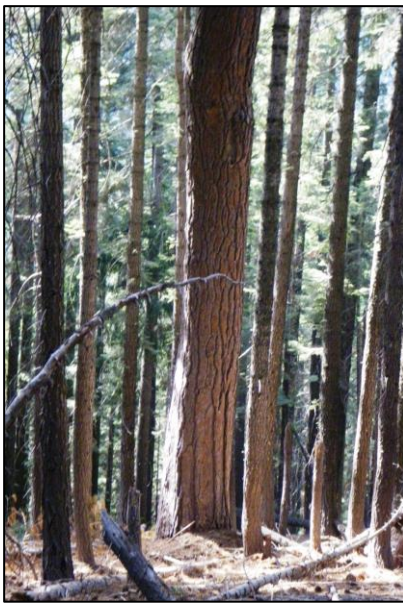


Figure 6. Large diameter ponderosa pine surrounded by smaller white fir in Unit 555.

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines and oaks should benefit by having the stocking around them reduced to lower levels. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees. Small group harvest could also be utilized to remove white fir that are within known Heterobasidion root disease centers, providing opportunities for planting non-host species. Incorporating the concepts of GTR 220 will address many of these issues and be consistent with Region 5 ecosystem restoration goals. Many of these methods are also consistent with past Forest Health Protection recommendations for thinning in mixed conifer stands and their use is supported for the Sacketts project.

In decadent red fir stands that are heavily infected with dwarf mistletoe and Cytospora canker, thinning treatments should emphasize a reduction in the number of heavily infected trees (i.e. mistletoe abundant throughout the crown), an increase in species diversity and the creation of openings that facilitate the establishment of dwarf mistletoe free regeneration. Dwarf mistletoe disperses most effectively from overstory trees to smaller trees of the same species. Thus, spread tends to be most efficient in multi-aged stands of the same host tree species. In areas where young regeneration is already established but not yet significantly infected with dwarf mistletoe,

moderate to heavily infected overstory trees can be removed to reduce the number of additional infections. In infected areas without understory trees, openings can be created to encourage healthy regeneration. These openings can vary in size but should be large enough to provide a significant buffer from infected overstory trees that can spread dwarf mistletoe seed horizontally up to 60 feet. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree.

Special consideration needs to be given to sugar pine and western white pine in the Sacketts project area. In general, western white and sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting openings created by any group selection harvest with rust resistant stock would help insure these species persist in the area.

Heterobasidion occidentale (fir type Heterobasidion root disease), although found in several locations throughout the project area, appears to exist in distinct centers, especially in the younger white fir stands. Since there may be large portions of white fir stands that have low levels of root disease or are possibly free of root disease, it is recommended that a registered borate compound be applied to all freshly cut true fir stumps >14" in diameter to reduce the chance of creating new infection centers through harvest activity. If further recon reveals more extensive root disease within harvest units, the treatment of white fir stumps may be ineffective. The treatment of all other conifer species stumps >14" in diameter, created through harvest activity, is recommended for the entire Sacketts project area.

Considerations for Rx fire

If prescribed fire is used as a follow-up treatment to stand thinning or as a standalone treatment, unacceptable levels of large diameter pine mortality may occur depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa and especially sugar pines are susceptible to mortality during prescribed burns because of the deep duff and litter that has accumulated at their base in the absence of fire. These duff mounds typically burn at a slow rate, while maintaining lethal temperatures, causing severe cambium injury. To protect individual large diameter pine from lethal cambium injury, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

White fir and red fir occurring in nearly pure stands tend to have very high levels of course woody debris on the forest floor as a result of downed logs from self-thinning, the continual shedding of branches and the remaining stems from old stands of brush that have been overtopped and killed by dense fir canopies. These types of stands produce tremendous amounts of heat on the ground surface and often cause severe injuries to the boles and crowns of standing trees, especially to smaller diameter trees. If high post-burn mortality levels in true fir stands, resulting in openings and possibly additional heavy fuel loading, is not an acceptable condition, than fuel treatments such as hand or tractor piling should be considered prior to or in place of prescribed fire. This is especially important in roadside units due to the potential for some fire-injured true fir to deteriorate into an unstable and hazardous condition.

Potential for funding through the Western Bark Beetle Program

Forest Health Protection may be able to assist with funding, including NEPA activities, for thinning and removing green material from overstocked areas within the Sacketts project area. Thinning treatments that reduce stand density sufficient to lower the risk to bark beetle-caused mortality would meet the minimum requirements for Western Bark Beetle Program funding and would be supported by this evaluation. If you are interested in this competitive funding please contact me for assistance in developing and submitting a proposal.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

/s/ Danny Cluck

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Fir engraver beetle

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4" in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4" in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year; however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Mountain pine beetle

The mountain pine beetle, *Dendroctonus ponderosae,* attacks the bole of ponderosa, lodgepole, sugar and western white pines larger than about 8 inches dbh. Extensive infestations have occurred in mature lodgepole pine forests. Group killing often occurs in mature forests and young overstocked stands of ponderosa, sugar and western white pines.

Evidence of Attack

The first sign of beetle-caused mortality is generally discolored foliage. The mountain pine beetle begins attacking most pine species on the lower 15 feet of the bole. Examination of infested trees usually reveals the presence of pitch tubes. Pitch tubes on successfully infested trees are pink to dark red masses of resin mixed with boring dust. Creamy, white pitch tubes indicate that the tree was able to "pitch out" the beetle and the attack was not successful. In addition to pitch tubes, successfully infested trees will have dry boring dust in the bark crevices and around the base of the tree. Attacking beetles carry the spores of blue-staining fungi which develop and spread throughout the sapwood interrupting the flow of water to the crown. The fungi also reduces the flow of pitch in the tree, thus aiding the beetles in overcoming the tree. The combined action of both beetles and fungi causes the needles to discolor and the tree to die.

Life Stages and Development

The beetle develops through four stages: egg, larva, pupa and adult. The life cycle of the mountain pine beetle varies considerably over its range. One generation per year is typical, with attacks occurring from late June through August. Two generations per year may develop in low elevation sugar pine. Females making their first attacks release aggregating pheromones. These pheromones attract males and other females until a mass attack overcomes the tree. The adults bore long, vertical, egg galleries and lay eggs in niches along the sides of the gallery. The larvae feed in mines perpendicular to the main gallery and construct small pupal cells at the end of these mines where they pupate and transform into adults.

Conditions Affecting Outbreaks

The food supply regulates populations of the beetle. In lodgepole pine, it appears that the beetles select larger trees with thick phloem, however the relationship between beetle populations and phloem thickness in other hosts has not been established. A copious pitch flow from the pines can prevent successful attack. The number of beetles, the characteristics of the tree, and the weather affect the tree's ability to produce enough resin to resist attack. Other factors affecting the abundance of the mountain pine beetle include nematodes, woodpeckers, and predaceous and parasitic insects. As stand susceptibility to the beetle increases because of age, overstocking, diseases or drought, the effectiveness of natural control decreases and pine mortality increases.

White fir sawfly

White fir sawfly (*Neodiprion abietis*) is a defoliator of white fir in northeastern California. Adult females deposit eggs in slits cut into needles. Overwintering egg clutches hatch in late May to early June and larvae feed from May through July. These larvae can be observed feeding in groups on older foliage. During outbreaks, defoliation is most pronounced in the understory trees and in the lower crowns of all trees. Active infestations may be detected by the fading, yellowish brown remnants of the 1 year or older needles as larvae seldom feed on the current year’s foliage. Mature larvae drop to the ground and enter the soil just beneath the duff to form cocoons. Adults fly, mate and lay eggs in late fall.

Previous outbreaks in California indicate that mortality is typically less than 1 percent and most commonly is observed in the intermediate and suppressed trees. In addition, there has not been any

evidence of bark beetles or borers attacking defoliated trees. Growth will be reduced in the short term as trees may take up to 5 years to fully recover their foliage.

White fir sawfly outbreaks are usually short in duration due to natural causes. White fir sawfly is attacked by many parasite and predators and is susceptible to a naturally occurring virus that is important in outbreak collapse. Due to these natural population controls, direct suppression is typically unnecessary.

Douglas-fir tussock moth

The Douglas-fir tussock moth is an important defoliator of true firs, primarily white fir, in California. Some level of outbreak by Douglas-fir tussock moth has been recorded in California about every 10 years. Outbreaks appear to develop almost explosively, and then usually subside abruptly after a year or two. Defoliation by the tussock moth kills or top-kills many trees, weakens additional trees that can be eventually killed by bark beetles, and may retard tree growth for several years.

Usually the first indication of attack appears in late spring. Larvae from the newly hatched eggs feed on current year's foliage, causing it to shrivel and turn brown. Older larvae may feed on both current and old foliage, although current needles are preferred. Defoliation occurs first in the tops of the trees and the outermost portions of the branches, and then in the lower crown and farther back on the branches.

The adult male is a gray-brouwn to black-brown moth with feathery antennae and a wingspread of 1 to 1 1/4 inches. The forewings are gray brown and have two distinct, irregular dark bars and two vague whitish spots. The hindwings are a contrasting brown. The female has tiny rudimentary wings, small threadlike antennae, and a large abdomen. Young larvae are 1/8 to 1/4 inch long and have long, fine body hairs which later develop into tufts. Mature larvae are up to 1 1/4 inches long and very colorful. Two long, dark tufts or pencils of hair similar to horns are located right behind the head. Four dense, buff colored tussocks are located forward along the middle of the back. The rest of the body except for the legs and head, is covered with short hairs radiating from red, buttonlike centers.

The tussock moth produces one generation each year. Females mate soon after they emerge from their pupal cocoon. Egg hatch in May or early June coincides with bud burst and shoot elongation of the host trees. The larvae pass through four to six instars and pupate toward the end of the summer. The pupal stage lasts from 10-18 days depending on temperature.

Many natural controls exist that keep the number of tussock moths low most of the time. If population levels are causing unacceptable resource damage, alternate methods of control are available. Management recommendations to prevent tree damage from tussock moth outbreaks involve four major activities: early detection, evaluation, suppression, and prevention. An early detection pheromone trap monitoring system is in place in California, however prevention is the ultimate goal of pest management. Silvicultural systems that reduce the number of susceptible hosts and decrease the multi-storied characteristics of host stands are recommended to prevent outbreaks. There is some indication that fir growing in pine sites an fir stands on warm, dry sites are most susceptible to damage.

Heterobasidion root disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentalis* (also called the 'S' type) and *H. irregularis* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregularis* (‘P’ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentalis* (‘S’ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentalis* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf mistletoe

Dwarf mistletoes (*Arceuthobium* spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

Cytospora canker of true firs

Cytospora abietis is a damaging, canker-inducing fungus that commonly occurs on true firs throughout their natural range in California, central and eastern Oregon, and frequently on firs and Douglas-fir elsewhere in the western United States. A weak parasite, it attacks only trees that have been debilitated by other disease-causing agents, drought, fire, insects, and human activities.

One of the important factors that predispose firs to infection by *C. abietis* is dwarf mistletoe. Practically all fir stands in California and Oregon infested with dwarf mistletoe are infested with this fungus. *C. abietis* more commonly infects branches invaded by dwarf mistletoe and in some stands nearly a fourth of all branches bearing mistletoe are infected. Thus, in mistletoe-infected fir stands, considerable branch killing occurs each year as a result of this canker organism and occasionally trees are killed. Because this fungus sometimes reaches damaging proportions, *C. abietis* can constitute a threat to the management of true firs.

White pine blister rust

White pine blister rust is caused by *Cronartium ribicola* an obligate parasite that attacks 5-needled pines and several species of *Ribes* spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on *Ribes* spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to *Ribes* spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other *Ribes* spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on *Ribes* spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to *Ribes* spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to *Ribes* spp., its spread from *Ribes* spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.